

The Effect of Ortho- and Polyphosphates on the Properties of Iron Particles and Suspensions Derived from the Oxygenation of Fe(II)

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Iron Corrosion, Iron Release, and Red Water

- Particle formation
- Discolored water
- Staining of fixtures, clothing
- Metallic tasting water
- Flow restriction
- Oxidant demand
- Biofilm



Iron Release Pathways

- **Physical route**
 - abrasion or erosion of pipe scale
 - changes in water flow patterns
- **Chemical**
 - dissolution of scale
 - oxidation/reduction
 - ferrous or ferric iron
 - precipitation/particle generation

Key Iron Release Model Features

Role of Particles/Colloids

- When oxygen and chlorine are in contact with scale, ferrous ions are oxidized within the scale or close to the surface- *particles incorporated in scale*
- When oxidants are not present at surface, ferrous iron can diffuse into solution and is oxidized further out- *particles form in bulk water*

Phosphates in Drinking Water Treatment

- Orthophosphate
 - Lead (and copper) solubility reduction, corrosion control
 - Iron corrosion, iron release and red water reduction?
- Polyphosphates (variety of formulations, chain lengths, blends, etc.)
 - Prevent Fe, Mn, Ca precipitation, “sequesterent”
 - Corrosion and metal release control?
 - Complex metals (Pb)
 - Many are proprietary in nature, guidelines for their usage are unclear
 - Manufacturer experience
 - Trial and error
 - Science limited

Research Objectives

- **Examine the effect of orthophosphate and several polyphosphate formulations on the properties of iron colloids/particles**
 - Structure, size, shape, surface charge, crystalline nature
- **Examine the effect of orthophosphate and several polyphosphate formulations on the properties of iron suspensions**
 - Color, turbidity, stability

Particle Generation Reactor



Phosphates Used in this Study

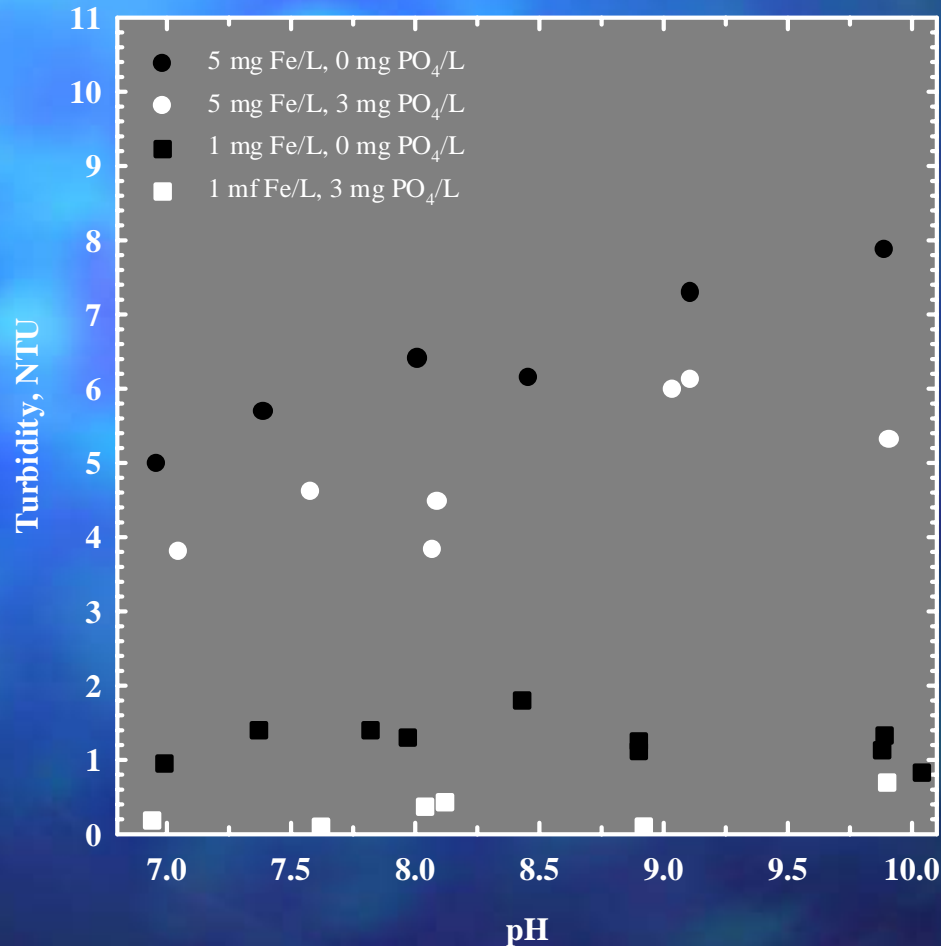
- Orthophosphate, **OP** (Na_3PO_3)
- Pyrophosphate, **PP** ($\text{Na}_4\text{P}_2\text{O}_7$)
- Tripolyphosphate, **TPP** ($\text{Na}_5\text{P}_3\text{O}_{10}$)
- Long-chained polyphosphate with an average chain length of 13 PO_3 groups, **LCPP₁₃**, also called sodium hexametaphosphate



The Effect of Orthophosphate on Iron Particles and Iron Suspensions

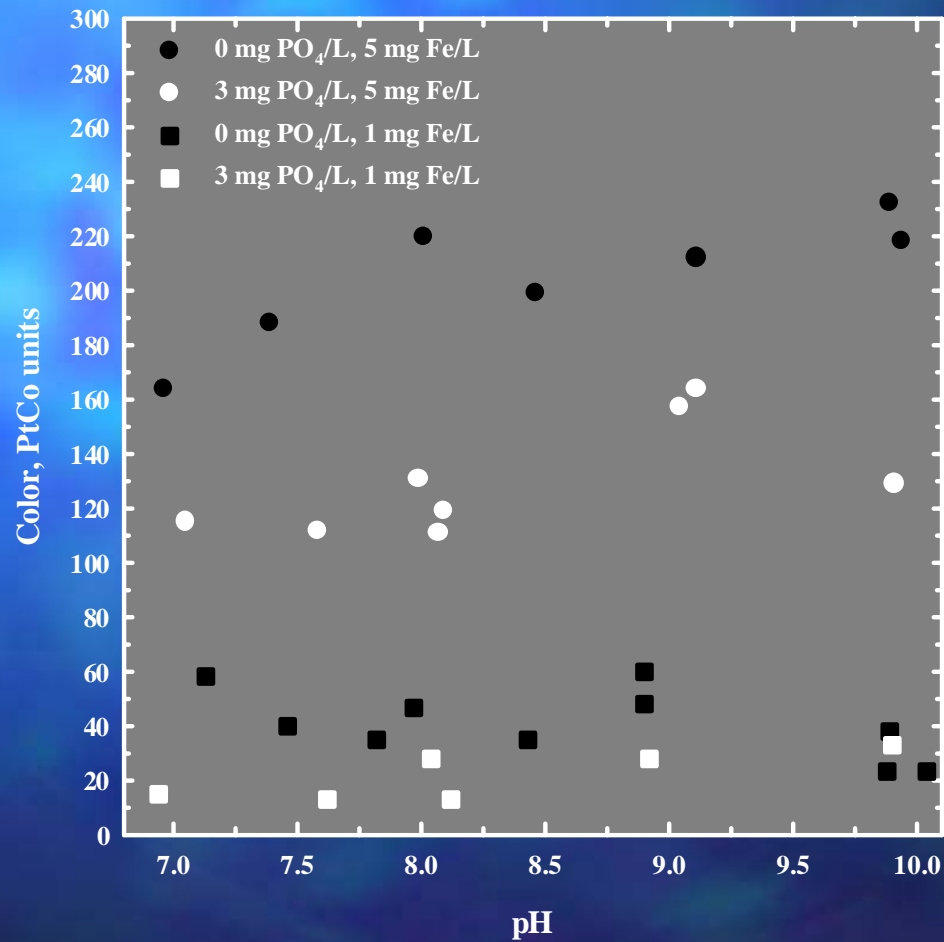
The Effect of Orthophosphate on Turbidity

DIC= 5 mg C/L, 0.122 atm O₂, 22°C



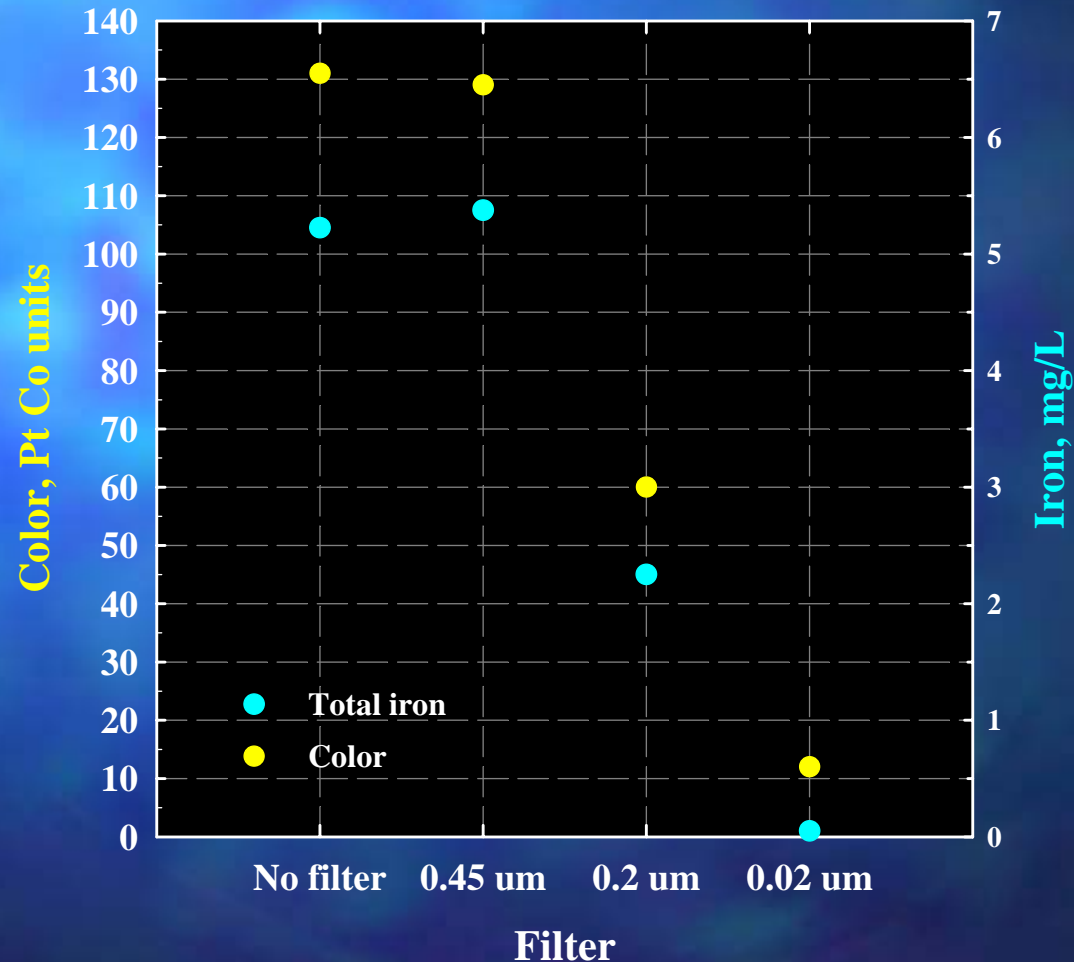
The Effect of Orthophosphate on Apparent Color

DIC= 5 mg C/L, 0.122 atm O₂, 22°C



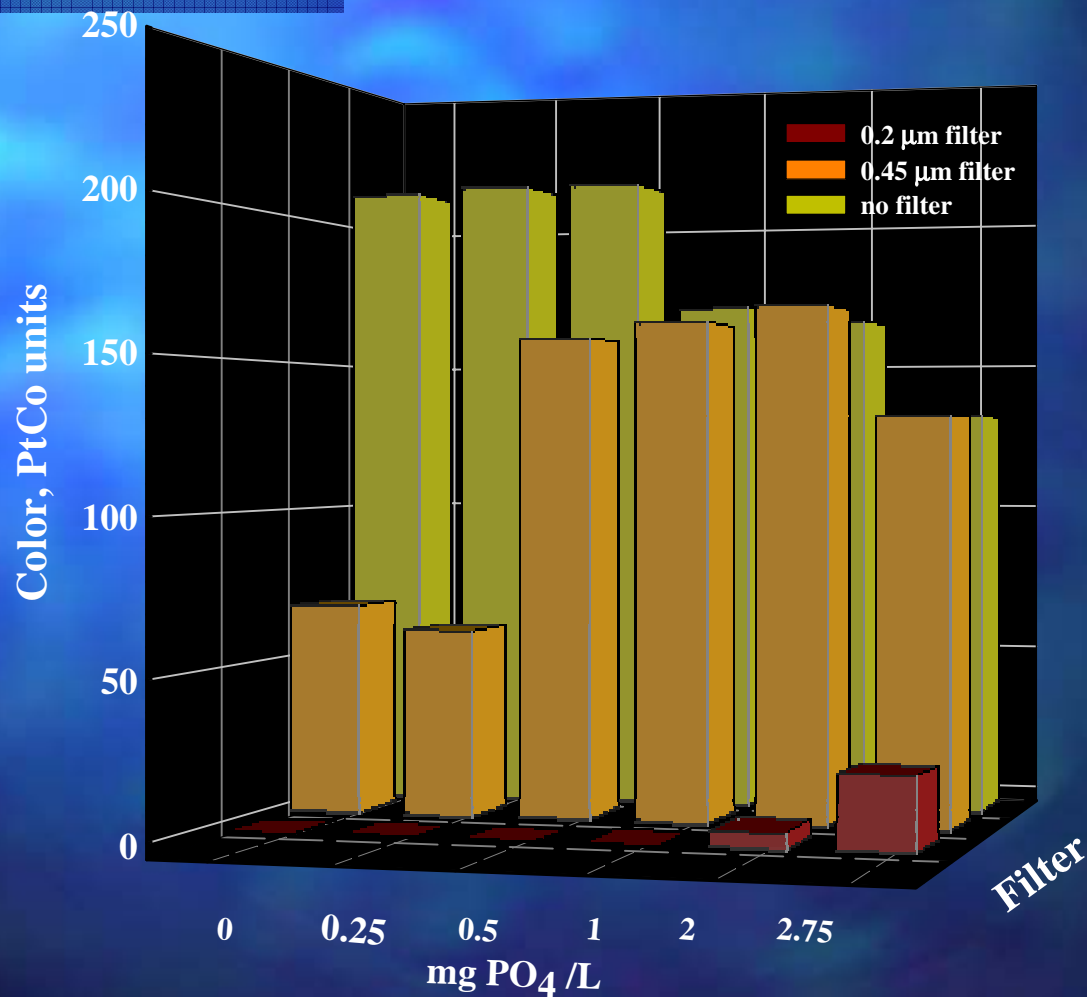
The Effect of Filtration on Color and Total Iron in the Presence of Orthophosphate

$\text{Fe}_{\text{tot}} = 5 \text{ mg/L}$, $\text{DIC} = 5 \text{ mg C/L}$, 0.122 atm O_2 , 22°C , $3 \text{ mg PO}_4/\text{L}$, $\text{pH } 8$, 22°C



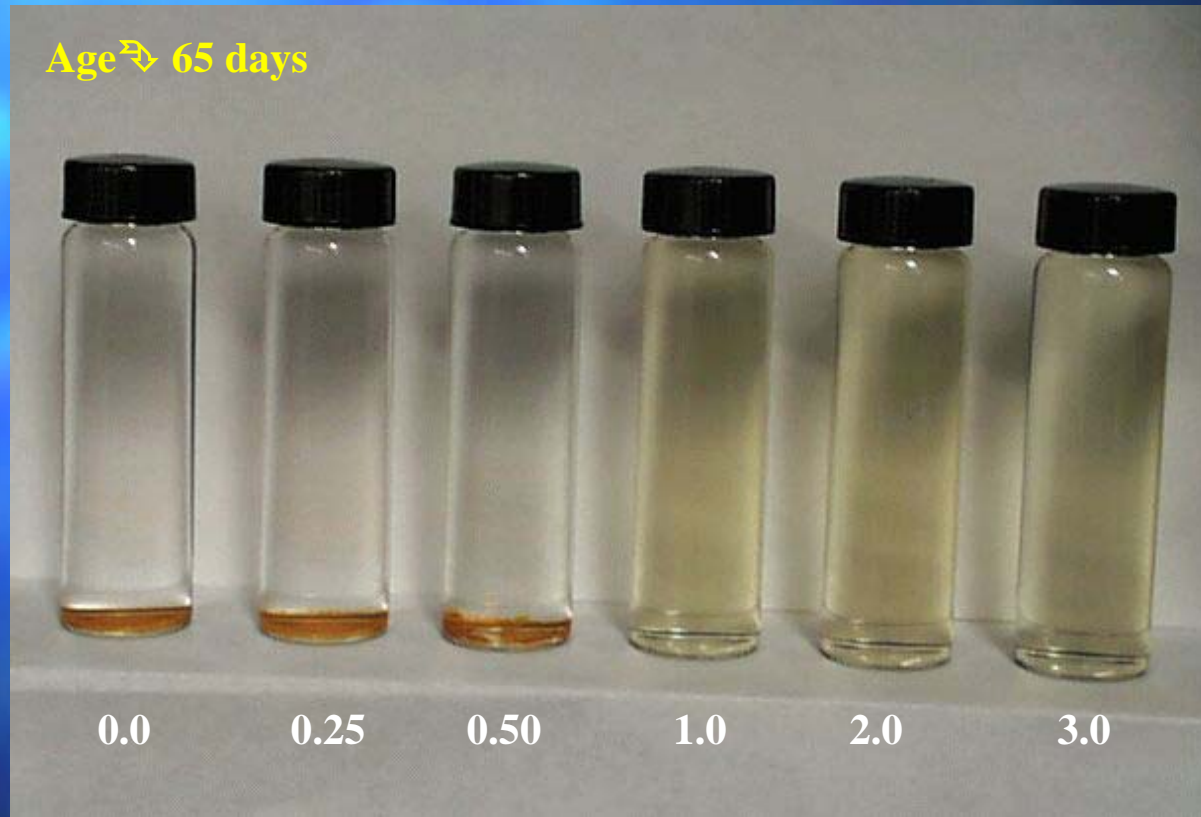
The Effect of Filtration on Color and Total Iron in the Presence of Orthophosphate

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Effect of Orthophosphate on Iron Suspension Stability

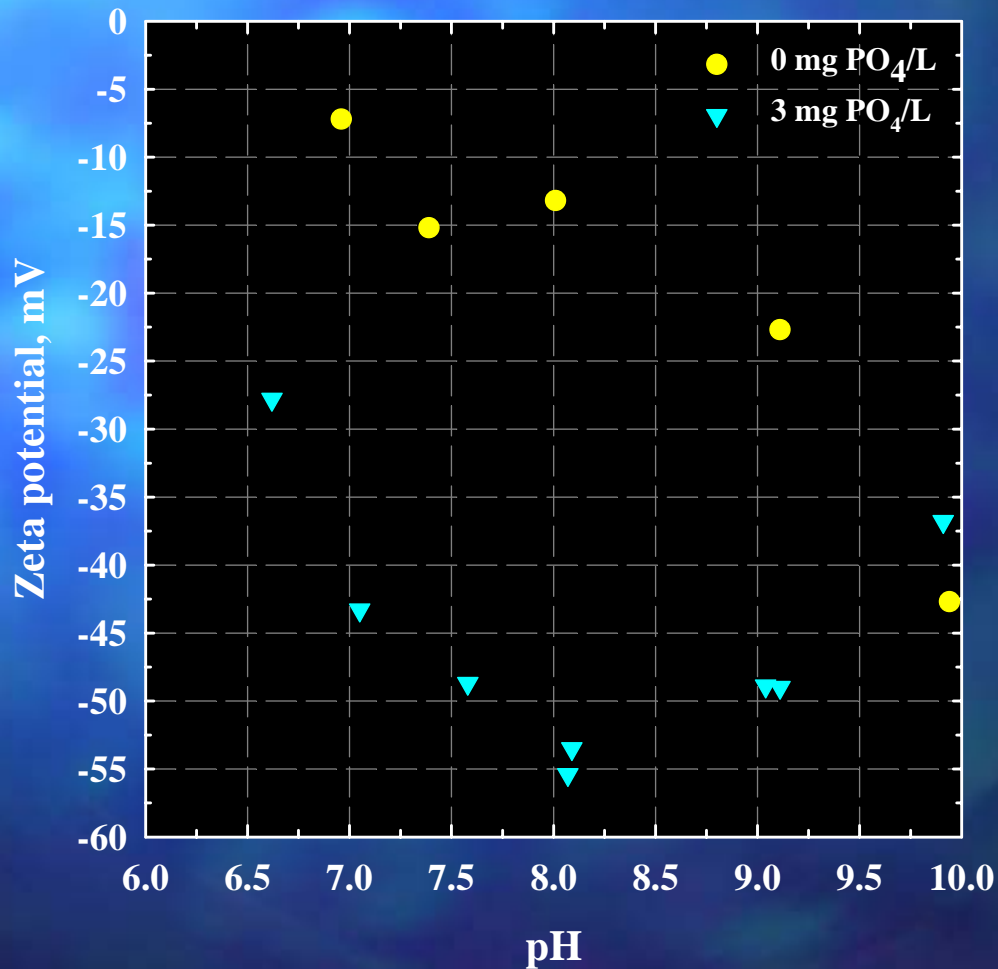
5 mg Fe/l, $\text{PO}_2 = 0.122$ atm, pH=8, DIC= 5 mg C/L, 22 °C



Phosphate, mg PO_4/L

The Effect of Orthophosphate and pH on ZP

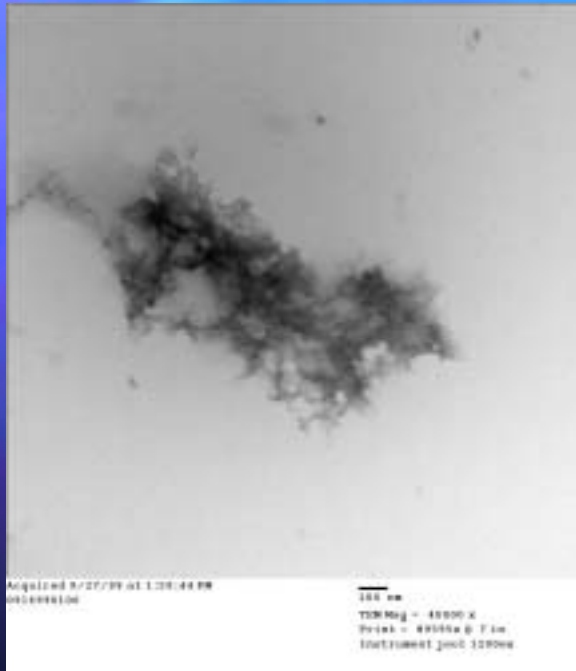
$\text{Fe}_{\text{tot}} = 5 \text{ mg/L}$, $\text{DIC} = 5 \text{ mg C/L}$, 0.122 atm O_2 , 22°C



The Effect of Orthophosphate on Iron Colloids

TEM micrograph of iron particles

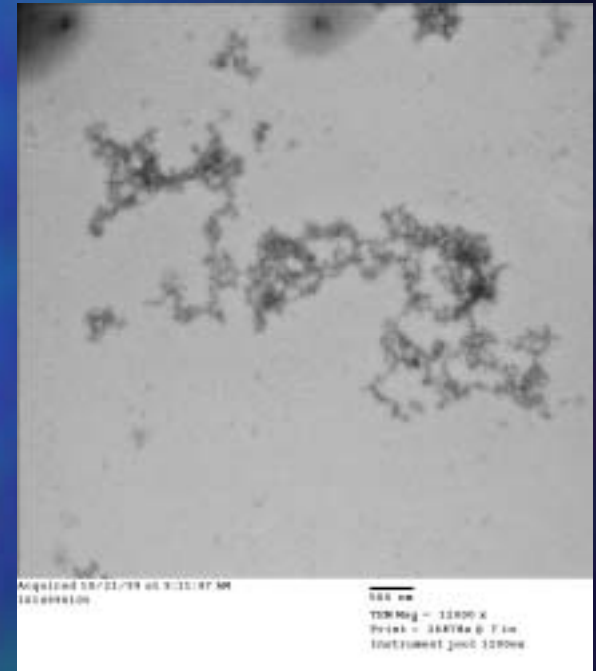
1 mg Fe/L, pH=7.85 to 7.89, 22.5 to 23°C, DIC= 5 mg C/L, PO₂=0.122 atm



0 mg PO₄/L



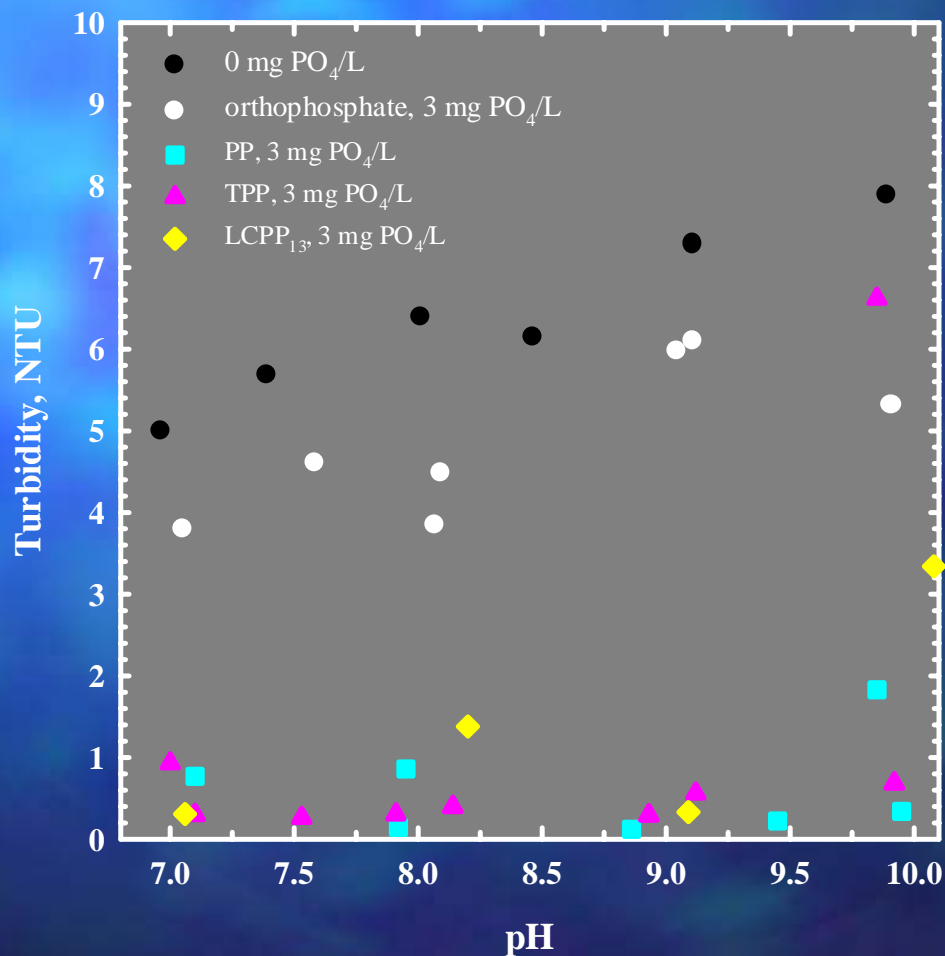
0.5 mg PO₄/L



3 mg PO₄/L

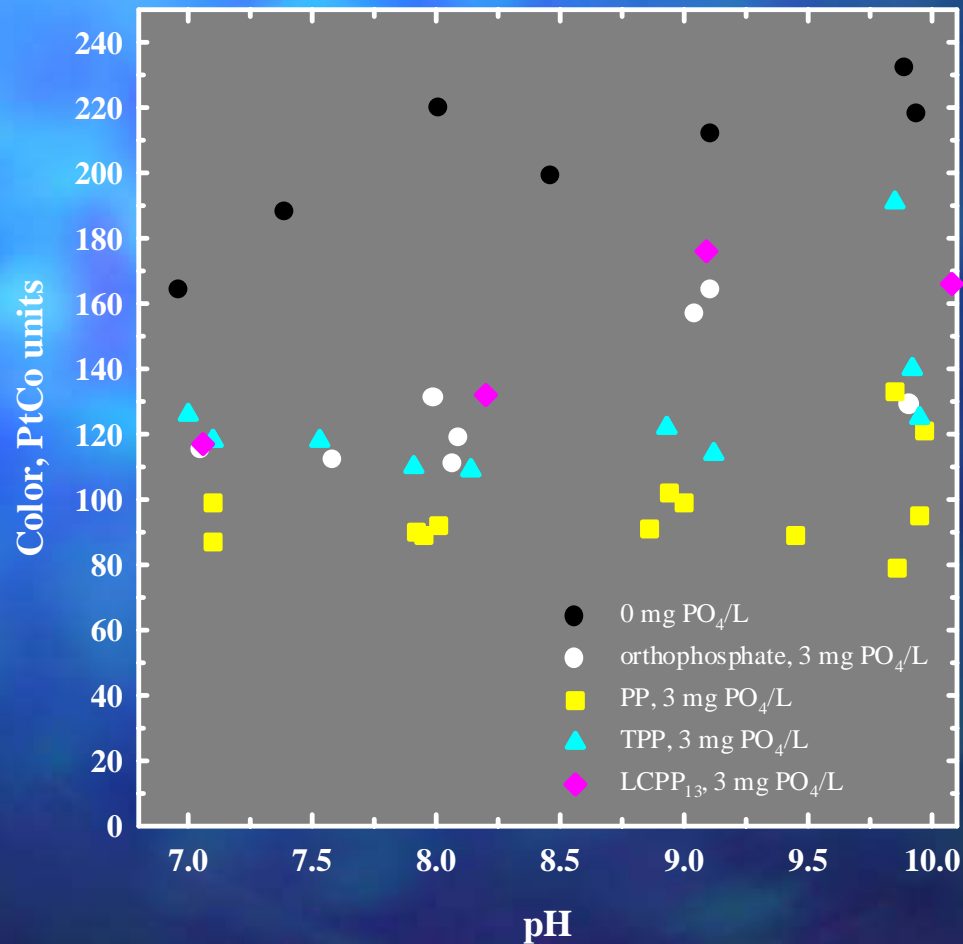
The Effect of Polyphosphates on Turbidity

$\text{Fe}_{\text{tot}} = 5 \text{ mg/L}$, $\text{DIC} = 5 \text{ mg C/L}$, 0.122 atm O_2 , 22°C , $3 \text{ mg PO}_4/\text{L}$



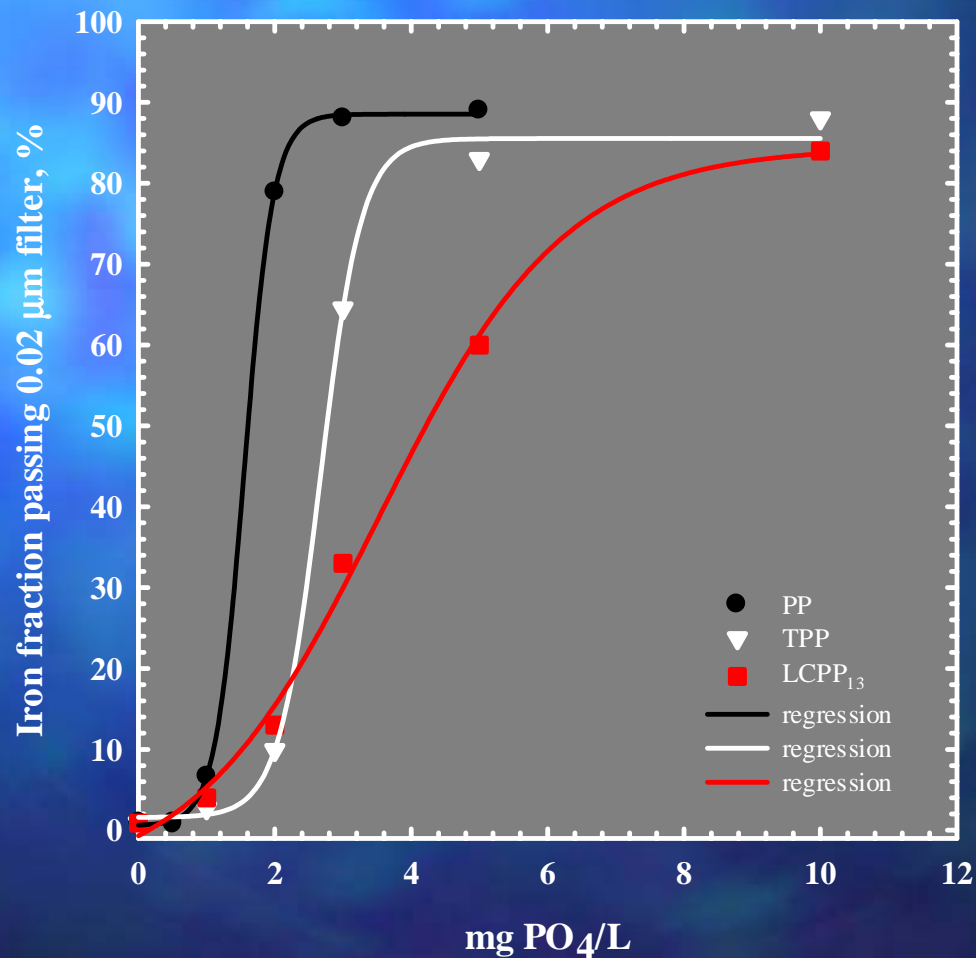
The Effect of Polyphosphates on Apparent Color

$\text{Fe}_{\text{tot}} = 5 \text{ mg/L}$, $\text{DIC} = 5 \text{ mg C/L}$, 0.122 atm O_2 , 22°C , $3 \text{ mg PO}_4/\text{L}$



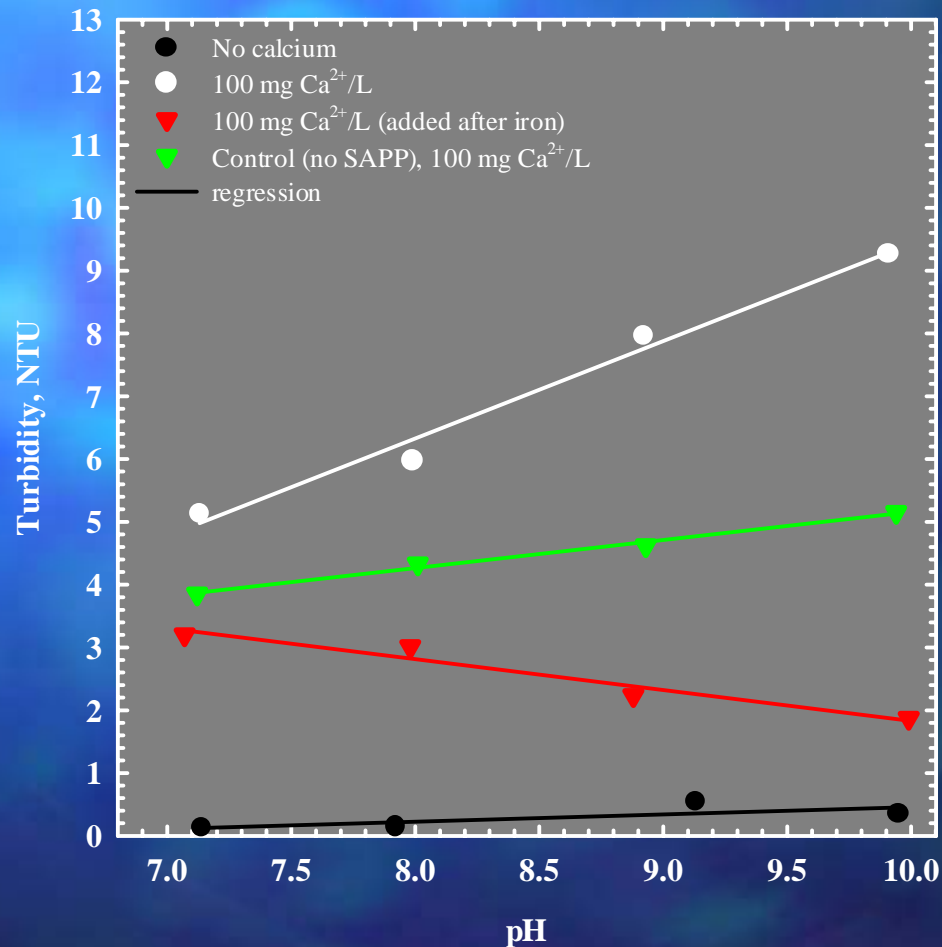
The Effect of Filtration on Total Iron in the Presence of Polyphosphates

$\text{Fe}_{\text{tot}} = 1 \text{ mg/L}$, $\text{DIC} = 5 \text{ mg C/L}$, 0.122 atm O_2 , 22°C , $\text{pH } 8$, 22°C



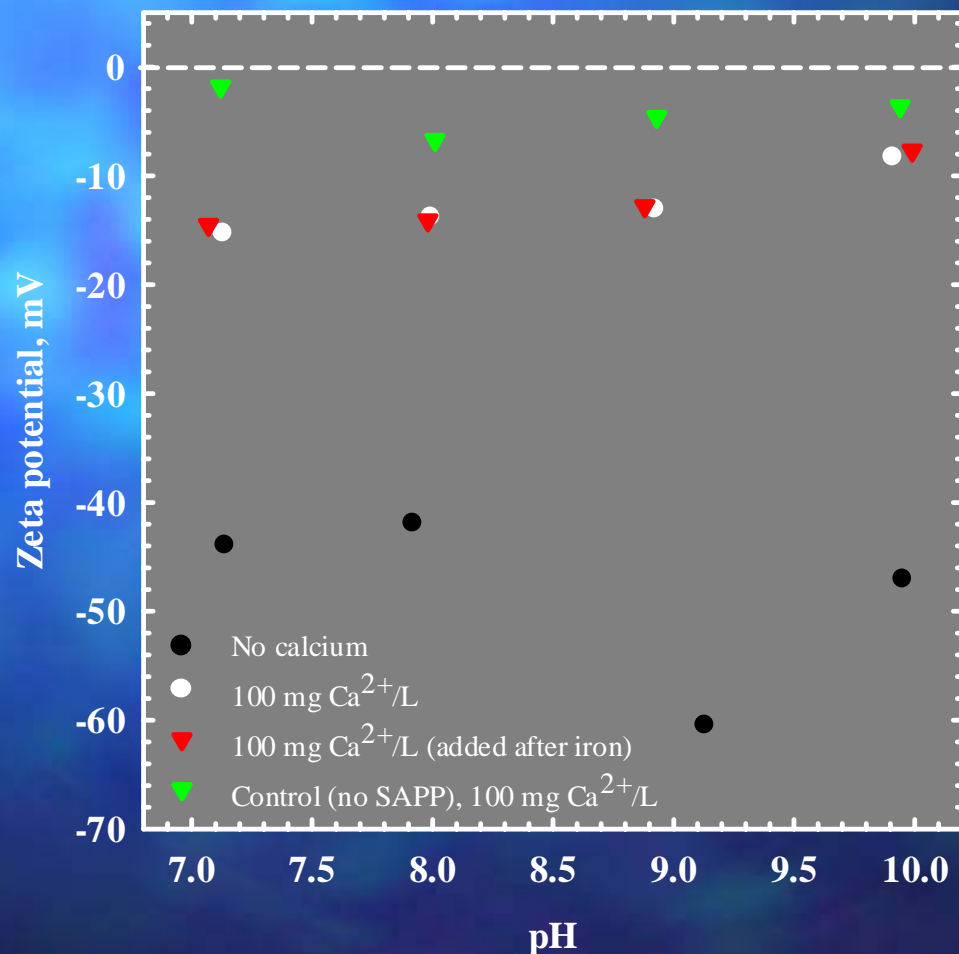
The Effect of Calcium, PP and pH on Turbidity

$\text{Fe}_{\text{tot}} = 5 \text{ mg/L}$, 3 mg PO_4 , $\text{DIC} = 5 \text{ mg C/L}$, 0.122 atm O_2 , 22°C



The Effect of Calcium, PP and pH on Zeta Potential

$\text{Fe}_{\text{tot}} = 5 \text{ mg/L}$, 3 mg PO_4 , $\text{DIC} = 5 \text{ mg C/L}$, 0.122 atm O_2 , 22°C



Considerations when Using Polyphosphates

- Ability to prevent precipitation
- Reversion rate (water chemistry)
- Complexation of metals (Pb, Cu)
- Knowledge
- Cost

The Effect of Orthophosphate on Iron Particles and Suspension

Summary

Orthophosphate...

- 1. Reduced suspension color and turbidity**
- 2. Adsorbed to iron colloid**
- 3. Increased the charge of iron colloids**
- 4. Stabilized iron colloids**
- 5. Inhibited colloid growth and flocculation**
- 6. Spherical particles having 200 nm diameter**

The Effect of Polyphosphates on Iron Particles and Suspension

Summary

- **Very effective at reducing turbidity and color**
- **Interacts with iron shortly after nucleation**
- **Highly charged colloids**
- **Shorter chained polyphosphates appeared to be more effective based on filterability**
- **The presence of major cations can have a major negative impact on suspension stability**

The End- THANK-YOU
